DOI: 10.1111/infa.12354

RESEARCH ARTICLE

INFANCY THE OFFICIAL JOURNAL OF THE INTERNATIONAL CONGRESS OF INFANT STUDIES WILEY

14-month-olds exploit verbs' syntactic contexts to build expectations about novel words

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Funding information
French Agence Nationale de la Recherche, Grant/Award Number: ANR-10-IDEX-0001-02 PSL, ANR-10-LABX-0087 IEC and ANR-13-APPR-0012; Fondation Fyssen; H2020 Marie Skłodowska-Curie Actions, Grant/Award Number: 799380

Abstract

During their second year of life, infants develop a rudimentary understanding of grammatical categories based on their knowledge and use of frequent function words. The current study inquired whether, at only 14 months of age, infants can track co-occurrence patterns between function words and content words (e.g., determiners can precede nouns, and pronouns can precede verbs), and use these previously encountered syntactic contexts to build expectations about which function words can co-occur with novel words. Using a habituation paradigm, French-learning 14-month-olds were presented with utterances containing two novel words preceded by function words (either two determiners in the Novel Nouns condition or two pronouns in the Novel Verbs conditions). We found that at test, infants looked longer during trials in which the novel words occurred in an unexpected syntactic context (following a pronoun for infants in the Novel Nouns condition and following a determiner for infants in the pooled analysis of the three Novel Verbs conditions). Hence, our results confirm previous findings on infants' sensitivity to noun contexts and most importantly demonstrate that their sensitivity to the co-occurrence of verbs with pronouns begins much earlier than previously understood.

1 | INTRODUCTION

When acquiring their native language, infants face the great challenge of assigning words to grammatical categories (e.g., noun, verb, adjective) and drawing inferences about their probable meanings. Since infant-directed speech is for the most part made up of sentences rather than isolated words (Aslin, 1993; Brent & Siskind, 2001; van de Weijer, 1998), infants base their inferences about novel words mainly from the surrounding cues, such as the neighboring words (as well as the visual context). This situation is not problematic according to the well-known mechanism called *syntactic bootstrapping* (e.g., Arunachalam, 2016; Bernal, Lidz, Millotte, & Christophe, 2007; Fisher, Gertner, Scott, & Yuan, 2010; Gillette, Gleitman, Gleitman, & Lederer, 1999; Gleitman, 1990), since the syntactic context of a word is highly informative with regard to its category, constraining its possible meaning and guiding children's visual attention toward specific parts of the world. For instance, a novel word such as "larp" appearing in a noun position (e.g., "This is a larp") can be interpreted as referring to a novel object, whereas if it appears in a verb position (e.g., "He is larping that"), it can be interpreted as referring to a novel event.[1] Accordingly, several studies have shown that infants from 18 months of age are able to use the other words of a sentence to infer the probable meaning of a novel word (e.g., Arunachalam & Waxman, 2011; Bernal et al., 2007; de Carvalho, He, Lidz, & Christophe, 2019; He & Lidz, 2017; Oshima-Takane, Ariyama, Kobayashi, Katerelos, & Poulin-Dubois, 2011; Waxman, Lidz, Braun, & Lavin, 2009). These findings beg the question of how young children come to learn about syntactic contexts.

Syntactic contexts are mostly formed of function words (e.g., "the," "a," "she," and "they"), which are so frequent that infants come to process, store, and recognize them during their first year of life (e.g., Hallé, Durand, & de Boysson-Bardies, 2008; Höhle & Weissenborn, 2003; Shafer, Shucard, Shucard, & Gerken, 1998; Shi, Cutler, Werker, & Cruickshank, 2006; Shi & Lepage, 2008; for a review: Shi, 2014). Soon after their first birthday, infants display a rudimentary understanding of grammatical categories based on their knowledge and use of frequent function words. Specifically, studies have found that infants can build expectations about the syntactic context in which novel nouns are likely to be next encountered, based on the contexts in which they have previously been heard (Höhle, Weissenborn, Kiefer, Schulz, & Schmitz, 2004; Shi & Melançon, 2010). For example, in Shi and Melançon (2010), Quebec-French-learning 14-month-olds were familiarized with two new words (e.g., *mige* and *crale*), preceded by two function words, either two pronouns (*je* "I" and *il* "he") or two determiners (*des* "some" and *ton* "your"). Both groups were tested with trials presenting a different noun context (e.g., *le mige* "the mige") and trials presenting a different verb context (e.g., *tu miges* "you mige"). The group familiarized with the noun phrases distinguished the two types of test trials, exhibiting longer looking times when the new content words were presented in the incongruent verb context. These results suggest that around 14 months of age, infants already know (some of) the syntactic contexts that support nouns, since they can generalize that a novel word heard in the context of two determiners is likely to also co-occur with a third one. In contrast, the 14-month-olds in Shi and Melançon (2010), as well as in Höhle et al. (2004, in German), did not seem able to draw any inference from having heard novel words in verb contexts, since they showed no listening preference, at test, for the novel words occurring in noun versus verb contexts. Sensitivity to verb contexts for novel verbs categorization seems to only emerge a few months later (e.g., Massicotte-Laforge & Shi, 2015).

[1]In the sentence "This is a larp", the novel word "larp" appears in a noun position, because it follows a determiner (it is part of a DP), and is part of a complement of the copula "is." In the sentence "He is larping that", "larp" appears in a verb position because it follows the auxiliary verb "is" as the main verb (with aspectual morphology), and is in a transitive frame.

Tracking the syntactic contexts of words may be an essential first step toward discovering the link between syntactic and semantic categories. From the literature discussed above, it is clear that shortly after their first year of life, infants have managed to efficiently track noun contexts, that is, nouns can follow different determiners (Höhle et al., 2004; Shi & Melançon, 2010). However, it is less clear if they have also managed to do so with verb contexts involving subject pronouns, since previous work failed to show evidence of generalization to different subject pronouns at that age. The distributional properties of nouns and verbs may partly explain this discrepancy in infants' ability to build expectations about novel words in laboratory settings. Based on a corpus in French (Cécyre & Shi, 2005), nouns appear in more stable contexts (i.e., consistently co-occurring with a preceding determiner in 71% of cases or with a preceding adjective in 26% of cases) than do verbs (i.e., preceded by a subject pronoun, 59%). Nonetheless, the co-occurrence of verbs with subject pronouns might still be noticeable early on. Given that at 14 months of age infants have acquired a receptive vocabulary that includes both frequent nouns and verbs (e.g., Bergelson & Swingley, 2013, 2015), it is plausible that they also track the contexts in which those known words occur. If that is the case, and infants have linked subject pronouns (e.g., *il* "he" and *tu* "you") to known verbs (memorizing sequences such as *il mange* "he eats" and *tu manges* "you eat"), then presenting known verbs along with to-be-learned novel words might help infants access what they already know about verb contexts. When encountering a novel word such as *dase* in the same contexts as a known word (e.g., *il dase* "he dases," *je dase* "I dase," *il mange* "he eats," and *je mange* "I eat"), infants could expect *dase* to occur in the syntactic context *tu dases* "you dase," based on its similarity with the known verb. This account is highly plausible based on a substantial body of work showing that preverbal infants are able to track patterns of co-occurrences in speech-only tasks (e.g., Gómez & Gerken, 1999), enabling them to create form-based categories around 12 months of age (e.g., Gerken, Wilson, & Lewis, 2005; Gómez & Lakusta, 2004).

The idea that known words play a role in early syntactic development has recently been put forward by the *semantic seed* hypothesis (Christophe, Dautriche, de Carvalho, & Brusini, 2016; Gutman, Dautriche, Crabbé, & Christophe, 2015, see also Christodoulopoulos, Roth, & Fisher, 2016), which also reiterates the importance of distributional cues for dividing words into syntactic categories. Based on this hypothesis, infants could exploit their early lexicon as a *seed* for assigning novel words into categories. The meaning of initial lexical items may be acquired from visual cues and through cross-situational learning. Using their distributional learning skills, infants would then track the syntactic contexts of these known words (e.g., "ball" and "car" appear in "This is a ball" and "This is a car") and later infer that a novel word appearing in the same context is likely to share some properties with these known words (e.g., "This is a" + "dax" -> dax = object). This end point follows the established proposal that young children expect words that share conceptual or semantic properties to occur in similar syntactic contexts (Gleitman, 1990; Pinker, 1984). In sum, before building semantic expectations about novel words based on syntactic cues (e.g., making deductions about the intended object referent via *syntactic bootstrapping*), infants would be capable of tracking co-occurrence patterns between function words and familiar content words.

The present research aimed at examining infants' ability to use words they already know to build expectations about the kind of syntactic contexts in which novel words would be likely to occur. Although our design was inspired by the distributionally based assumptions of the *semantic seed hypothesis*, we do not provide a direct test of its underlying mechanism. In Experiment 1, we tested 14-month-olds' ability to build expectations about novel words based on function word knowledge only. We expected to replicate previous findings from Shi and Melançon's study, namely that 14-month-olds would show the ability to build expectations about novel words encountered in noun contexts, but not about novel words encountered in verb contexts. In subsequent experiments, we examined whether infants can exploit the presence of a few known content words during the familiarization phase, occurring in

the same contexts as the novel words, to boost their performance: that is, to build expectations about the syntactic contexts in which the novel verbs would likely appear (i.e., following a pronoun in the test phase given that they followed pronouns in the familiarization phase). Note that the presence of a few known words within the familiarization phase makes the experiment more ecological, in that it is closer to what infants around one year of age hear in real life (i.e., novel words are likely to be introduced within conversations that also include known words).

2 | EXPERIMENT 1: BUILDING EXPECTATIONS BASED ON CO-OCCURRING FUNCTION WORDS ALONE

In Experiment 1, two groups of 14-month-olds were habituated to two novel words presented either in noun contexts (following determiners, Novel Nouns condition) or in verb contexts (following pronouns, Novel Verbs condition). To test whether infants were able to build expectations about upcoming contexts for the novel words, both groups were tested with trials presenting these same novel words within a different noun context and trials presenting them within a different verb context. Hence, one type of test trials presented the novel words in a context that was congruent with the one used during familiarization, while the other test trials presented them in an incongruent context. As in Shi and Melançon (2010), differential looking times during congruent versus incongruent trials would indicate that infants successfully predicted the type of function words that could co-occur with the novel words.

2.1 | Method

The study reported in this paper, including the entire method, analysis and criteria for exclusion of participants were pre-registered on the OSF (Open Science Framework) database before running the experiment. The pre-registration[2] can be accessed with the following link: https://osf.io/psqwk/. The materials, collected data, and data analyses are also freely available to readers through this link.

2.1.1 | Participants

A total of 56 French-learning monolingual 14-month-olds (28 in each group) with no known hearing problems participated in the experiments (Novel nouns group: mean age: 14 months, 0 days; age range: 13 months, 18 days–14 months, 14 days; 14 girls; Novel verbs group: mean age: 14 months, 0 days; age range: 13 months, 18 days–14 months, 13 days; 17 girls). An additional 12 infants were tested in the Noun condition, but excluded from the analyses due to extreme fussiness/crying (8), failure to habituate (1), or parental interference (3). An additional nine infants were tested in the Verb condition, but excluded from the analyses due to fussiness/crying (4), failure to habituate (2), technical failure (1), parental interference (1), or experimenter error (1).

The present study was conducted at the Babylab of the École Normale Supérieure in Paris according to guidelines laid down in the Declaration of Helsinki, with written informed consent obtained from a parent or guardian for each child before any assessment or data collection. Since our study involves human subjects, it was carried out in accordance with the recommendations of our local

[2]Note that an amendment to the original pre-registration containing information about Experiment 3 was added later on.

TABLE 1 Stimuli of Experiment 1

Habituation	
Novel Nouns condition: Noun contexts	**Novel Verbs condition: Verb contexts**
Des dases "Some dases"	Je dase "I dase"
Des nuves "Some nuves"	Je nuve "I nuve"
Ton dase "Your dase"	Il dase "He dases"
Ton nuve "Your nuve"	Il nuve "He nuves"
Test	
Noun context: un dase "a dase," un nuve "a nuve"	
Vs	
Verb context: tu dases "you dase," tu nuves "you nuve"	

ethics committee, the CERES (*Comité d'éthique de la recherche en santé*—Paris), which approved our protocol beforehand.

2.1.2 | Stimuli

We used two pseudo-words, *dase* [daz] and *nuve* [nyv], which conform to the phonological structure of French. They appeared in short utterances, either in a noun position after a determiner (i.e., in a Det + N structure, where Det was as follows: *des* "some"; *ton* "your"; and *un* "a" for the test phase) or in a verb position after a subject pronoun (i.e., in a Pron + V structure where Pron was as follows: *il* "he"; *je* "I"; and *tu* "you" for the test phase).

A female native French speaker (the last author) recorded multiple repetitions of the 12 utterances in child-directed speech style (sampling frequency 44.1 kHz). All utterances were used in the habituation phase, except for utterances using the determiner *un* "a" and the pronoun *tu* "you" which were reserved for the test phase. The final stimuli consist of three exemplars of the eight habituation utterances (four noun contexts and four verb contexts) and six exemplars for each of the four test utterances.

For each condition, we created three different habituation lists which contained 16 utterances in different orders (e.g., for the Novel Nouns condition, each list contained four repetitions of *des dases* [dedaz], *des nuves* [denyv], *ton dase* [tɔ̃daz], and *ton nuve* [tɔ̃nyv]; see Table 1 for a full list of utterances). We also created two different lists used as test trials (one for verb contexts and one for noun contexts) which contained 16 utterances (e.g., for the test trials with noun contexts, there were eight repetitions of *un nuve* and eight of *un dase*). The maximal length of a habituation trial was 29.5 s, whereas the maximal length of a test trial was 27.5 s. Within a trial (habituation and test), the order of the utterances was pseudo-randomized with two restrictions: A particular utterance could not appear more than twice in a row, and the same novel pseudo-word could not occur more than twice in a row. In French, the final "s" in plural nouns is silent, making it possible to create ambiguous new content words (e.g., *dase* is pronounced as [daz] in both types of utterances, noun context: *des dases* [dedaz] "some dases"; verb context: *il dase* [ildaz] "he dases"). In addition, the acoustic properties of the novel pseudo-words in noun versus verb contexts were carefully balanced (see Table 2 for the mean acoustic measures for all stimuli).

TABLE 2 Average acoustic values (and *SD*) across multiple exemplars of the novel words (NW) and function word (FW) stimuli

Acoustic measure	Mean for noun uses	Mean for verb uses	Two-tailed *t* tests*
Total utterance duration (s)	1.097 (0.172)	1.116 (0.21)	$t(46) < 1$
FW duration (ms)	179 (44)	179 (40)	$t(46) < 1$
FW mean pitch (Hz)	268.6 (65.15)	271.6 (67.92)	$t(46) < 1$
FW mean intensity (dB)	78.42 (3.145)	78.16 (3.182)	$t(46) < 1$
NW duration (ms)	918 (147)	937 (196)	$t(46) < 1$
NW vowel duration (ms)	577 (13)	578 (154)	$t(46) < 1$
NW vowel mean pitch (Hz)	260.4 (28.32)	253.7 (27.95)	$t(46) < 1$
NW vowel mean intensity (dB)	77.37 (2.605)	76.7 (2.167)	$t(46) < 1$

*Note that *t* values varied from −1 to 1, with $p > .05$ for all analyses.

An animation of a bird moving its mouth in synchrony with the audio stimuli was presented during each trial. As an attention-getter to attract infants' attention toward the screen between trials, we used a silent video of a butterfly perched on a leaf.

2.1.3 | Design

The experiment contained two phases, a habituation phase and a test phase. Infants were randomly assigned to one of two habituation conditions (i.e., Novel Nouns condition vs. Novel Verbs condition). Infants in the Novel Nouns condition were familiarized with trials presenting the two pseudo-words preceded by two determiners: *ton* "your" and *des* "some." Infants in the Novel Verbs condition were familiarized with trials presenting the pseudo-words preceded by two pronouns: *je* "I" and *il* "he." Once infants reached the habituation criterion (see Procedure), the habituation phase ended and the test phase started automatically.

In the test phase, both groups were presented with the same stimuli containing the pseudo-words. There were two types of test trials: verb contexts involving the pronoun *tu* "you," and noun contexts involving the article *un* "a." Both trial types contained a context that was not used in the habituation (i.e., a different pronoun and a different article); the only difference between the two trial types was that one is a verb context and the other a noun context. Hence, one type of test trials was congruent with the syntactic contexts in which the pseudo-words were presented during the habituation and the other one was incongruent. For instance, for infants in the Novel Verbs condition, the test trials presenting the pseudo-words following the pronoun *tu* (i.e., *tu dases* and *tu nuves*) were congruent with the habituation phase, whereas the test trials presenting the pseudo-words following the article *un* (i.e., *un dase* and *un nuve*) were incongruent.

2.1.4 | Procedure

Infants were tested individually using a habituation paradigm implemented in a central fixation procedure. In a sound-attenuated double-walled booth, each infant sat on its caregiver's lap about 70 cm in front of a wall-mounted 27-inch monitor. Caregivers were instructed not to talk or point toward

the screen. Sound was presented to the infant through two loudspeakers, positioned on each side of the monitor. Caregivers listened to music through noise-canceling headphones to prevent them from hearing the stimuli. A camera above the monitor was connected to a monitor placed outside the booth. This setup enabled the experimenter to observe infants' reaction from an adjacent room without being aware of the stimuli presentation.

We presented the stimuli using Habit (Cohen, Atkinson, & Chaput, 2004). From the adjacent room, the experimenter pressed a computer key to initiate a trial when the infant looked toward the monitor, and she pressed another key whenever a look toward the monitor occurred during a trial. Trials ended either after the infant looked away from the screen for more than two consecutive seconds or after the maximum trial length was reached. A new trial started when the infant looked back toward the screen.

The habituation criterion was reached when an infant's average looking time during any block of three consecutive trials dropped to less than 65% of the average looking time for the most-attended block (i.e., the 3-trial block that has the longest total looking time). The total number of habituation trials each infant received could be different (between a minimum of four and a maximum of 12 trials). The presentation order of the habituation trials was counterbalanced across infants, and the three trials formed a block which could be repeated up to four times (i.e., each trial could either be presented as the first, second, or third trial of the block). The test phase began either with a trial presenting the pseudo-words in verb contexts or a trial presenting the pseudo-words in noun contexts. The order of presentation was counterbalanced across infants (N V N V or V N V N). The two types of trials alternated for a total of four trials (two of each type).

Our experiment was inspired by Shi and Melançon (2010), with three main differences. First, Shi and Melançon used a familiarization paradigm with a predetermined 30-s exposure, whereas we chose to use a habituation paradigm with a length of exposure determined by the infant. A habituation paradigm has the advantage of facilitating the prediction of the results, since a novelty effect (i.e., here, longer looking times during incongruent trials) is expected. Second, we chose different pseudo-words (i.e., *nuve* and *dase* vs. *mige* and *crale* in Shi & Melançon). Third, we chose the indefinite determiner *un* "a" for the test phase instead of the definite *le* "the," since *le* can act as an object clitic when preceding a verb (e.g., *je le mange* "I eat it") as well as a determiner (e.g., *le ballon*, "the ball").

2.2 | Results and discussion

Each infant's average looking times for the test trials presenting noun contexts and for those presenting verb contexts were calculated. The data for all infants were analyzed in a 2 × 2 analysis of variance (ANOVA) with Condition (Novel Nouns vs. Novel Verbs habituation phase) as a between-participant factor and Test Trial Type (noun vs. verb context) as a within-participant factor. The results showed no effect of Condition ($F(1, 54) = 0.036$, $p = .85$, $\eta^2 = 0.001$), nor of Test Trial Type ($F(1, 54) = 0.824$, $p = .368$, $\eta^2 = 0.014$). However, the interaction between Condition and Test Trial Type was significant ($F(1, 54) = 5.64$, $p = .021$, $\eta^2 = 0.093$). Follow-up paired t tests assessed infants' performance in each condition. For the Novel Nouns condition, looking time was significantly longer for the trials presenting verb contexts (i.e., incongruent trials) ($M = 13.71$, $SE = 1.364$) than for the trials presenting noun contexts (i.e., congruent trials) ($M = 10.51$, $SE = 1.248$), $t(27) = 2.135$, $p = .042$, $d = 0.404$. However, infants in the Novel Verbs condition showed no significant difference between the congruent test trials presenting verb contexts ($M = 11.12$, $SE = 1.269$) and the incongruent test trials presenting noun contexts ($M = 12.54$, $SE = 1.048$), $t(27) = -1.147$, $p = .262$, $d = -0.217$.

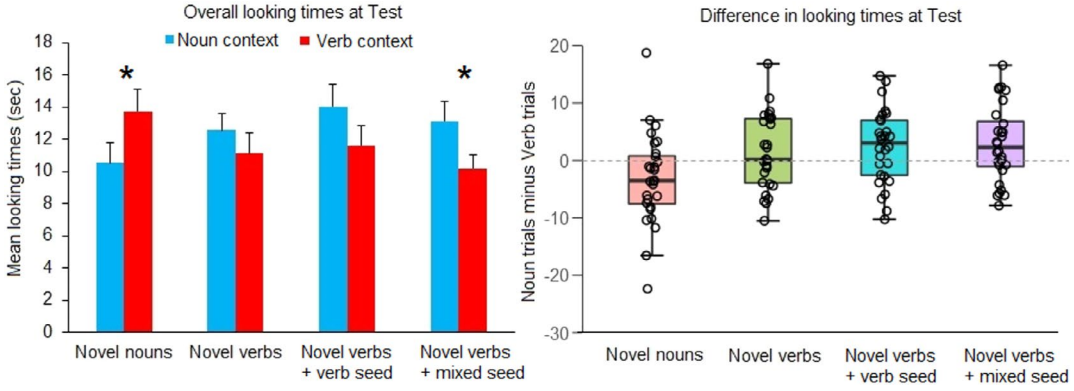

FIGURE 1 On the left side: Mean looking time in seconds during the two trial types, that is, noun contexts (in blue) and verb contexts (in red), for the conditions (Experiment 1: Novel Nouns and Novel Verbs; Experiment 2: Novel Verbs + Known Verbs; Experiment 3: Novel Verbs + Mixed Known Words). Error bars represent the standard error of the mean. On the right side: Box plot of the difference between looking times during the noun context and the verb context test trials for the four conditions. The black line represents the median. Each dot represents one participant. Successful categorization is indicated by longer looking times during the incongruent context (verb contexts for the Novel Nouns condition; noun contexts for the three Novel Verbs conditions)

As shown in Figure 1, infants in the Novel Nouns condition looked significantly longer when the context was incongruent with their expectations, that is, when the novel words appeared in a verb context (red bars), than when it was congruent with their expectations, that is, when the novel words appeared in a noun context (blue bars). A total of 20 infants out of 28 showed that pattern of looking times, which is consistent with the interpretation that infants from the Novel Nouns condition were able to create expectations as to the syntactic context in which the novel words were likely to be next encountered: Based on the habituation phase, in which the novel words occurred in noun contexts (following determiners), they were able to expect the novel nouns to occur after another determiner, but not after a subject pronoun. In contrast, infants in the Novel Verbs condition did not look significantly longer during the trials presenting incongruent noun contexts relative to the ones presenting congruent verb contexts, with only 15 infants out of 28 showing the expected pattern of listening times (although numerically, there was a trend in the right direction). Crucially, the significant interaction between Condition and Test Trial Type shows that the two groups of infants behaved significantly differently; therefore, the longer looking times for incongruent contexts for infants from the Novel Nouns condition are not due to an intrinsic preference for verb contexts. These results confirmed previous findings, since Shi and Melançon (2010) also observed that 14-month-olds exposed to noun contexts successfully generalized to another noun context, while infants familiarized with verb contexts did not show the ability to generalize to another verb context.

3 | EXPERIMENT 2: CAN FAMILIAR LEXICAL WORDS BOOST INFANTS' ABILITY TO BUILD EXPECTATIONS FOR VERBS?

In Experiment 2, 14-month-olds were habituated to two novel words in verb contexts (following pronouns), just as in Experiment 1. To test whether presenting known verbs during the habituation phase would increase infants' performance, the habituation trials also contained familiar verbs in the same

contexts as the novel words (e.g., *il dase* "he dases" and *il mange* "he eats"). The same test trials as in Experiment 1 (i.e., a noun context vs. another verb context) were used. If infants learn co-occurrence patterns by relying on a handful of words they know, then reminding them which known words occur in verb contexts might help them build expectations about what other contexts would be valid for the novel words (i.e., following the pronoun *tu* "you," but not following the determiner *un* "a").

3.1 | Method

3.1.1 | Participants

A total of 28 French-learning monolingual 14-month-olds with no known hearing problems participated in the experiment (mean age: 14 months, 0 days; age range: 13 months, 17 days–14 months, 13 days; 14 girls). An additional 14 infants were tested, but excluded from the analyses due to extreme fussiness/crying (6), failure to habituate (3), parental interference (3), technical failure (1), or experimenter error (1).

3.1.2 | Stimuli, design, and procedure

The design and the procedure were the same as in Experiment 1, except that only one group of infants was tested, and this group was familiarized with verb contexts. In addition to the two pseudo-words, we used four frequent known verbs: *donne* "give," *dort* "sleep," *mange* "eat," and *regarde* "look." These familiar verbs appeared in the same contexts as the pseudo-words, following the pronouns *il* "he" and *je* "I." These eight utterances were recorded by the same speaker as in Experiment 1, and three exemplars of each utterance were kept for the final stimuli. We created three new habituation lists including both the utterances with novel words (those used in Experiment 1) and the ones with known verbs. The utterances were pseudo-randomized with two restrictions: A particular utterance could not appear twice in a row, and one of the novel pseudo-word occurred at least once every two utterances (e.g., *il nuve*, *il regarde*, *je nuve*, and *je dors*). Each habituation list contained 16 utterances (half with familiar verbs and half with pseudo-verbs) in different orders and lasted 29.5 s. The stimuli for the test phase were identical to those in Experiment 1.

3.1.3 | Results and discussion

As in Experiment 1, each infant's average looking time for the test trials presenting noun contexts and for those presenting verb contexts were calculated. The data from the Novel Nouns condition of Experiment 1 were analyzed along with the Novel Verbs + Known Verbs condition from Experiment 2 in a 2 × 2 analysis of variance (ANOVA) with Condition (Novel Nouns vs. Novel Verbs + Known Verbs) as a between-participant factor and Test Trial Type (noun vs. verb syntactic context) as a within-participant factor. The results showed no main effect of Condition ($F(1, 54) = 0.196$, $p = .66$, $\eta^2 = 0.004$), nor of Test Trial Type ($F(1, 54) = 0.167$, $p = .685$, $\eta^2 = 0.003$). As in Experiment 1, the interaction between Condition and Test Trial Type was significant ($F(1, 54) = 8.411$, $p = .005$, $\eta^2 = 0.134$), that is, the two groups behaved differently. A follow-up paired t test assessed infants' discrimination in Experiment 2. This time, with a habituation to both pseudo-words and familiar verbs following pronouns, the difference between the congruent test trials presenting verb contexts

(M = 11.60, SE = 1.210) and the incongruent test trials presenting noun contexts (M = 14.01, SE = 1.393) approached significance, $t(27) = -1.971$, $p = .059$, $d = -0.372$. A total of 18 infants out of 28 showed the expected pattern of listening times.[3]

The presence of familiar verbs in the habituation phase slightly increased 14-month-olds' looking times toward syntactic contexts that were incongruent with what they heard during familiarization. To test whether infants' behavior differed between Experiment 1 and Experiment 2, we conducted a direct comparison between the two verb groups (Novel Verbs in Exp. 1 vs. Novel Verbs + Known Verbs in Exp. 2): This analysis did not reveal a significant interaction between Condition and Trial Type ($F(1, 54) = 0.315$, $p = .58$, $\eta^2 = 0.005$), suggesting that the two groups of infants behaved similarly. However, it did reveal a significant main effect of Test Trial Type ($F(1, 54) = 4.834$, $p = .032$, $\eta^2 = 0.082$), reflecting the fact that infants looked significantly longer overall for the incongruent syntactic contexts. This result suggests that 14-month-olds were able to build expectations about the syntactic contexts in which the novel verbs were likely to appear (i.e., following a subject pronoun). This effect appears to not be very strong, since it is observed only with the added power of the two groups of infants pooled together (56 infants total).

Although the analysis pooling Experiments 1 and 2 together suggests that infants are able to build expectations about the contexts in which novel verbs are likely to occur, 14-month-olds might have shown the observed behavior simply because they noticed that the habituation phase contained only one kind of function words (only personal pronouns), and they were surprised at test to hear a function word from a different category (and this holds for both Experiment 1 and Experiment 2). Under that interpretation, infants might have ignored the novel words and reacted to an unexpected function word during the test phase; as a result, they might not have made any predictions linked to the novel words themselves. To test whether infants paid attention to the novel words (not only to the function words) and used the familiarized verb contexts to build expectations about the novel verbs, the familiarization phase in Experiment 3 included both known verbs and known nouns (in addition to the novel verbs). This follow-up experiment alleviates the above concern, in that it allows us to test the hypothesis that infants use the specific contexts in which novel words have been encountered to build syntactic expectations about these novel words. It also provides a welcome replication.

4 | EXPERIMENT 3: CAN INFANTS BUILD EXPECTATIONS ABOUT NOVEL VERBS BASED ON THE SPECIFIC SYNTACTIC CONTEXTS IN WHICH THEY APPEAR?

In this experiment, 14-month-olds were familiarized with a mixed list containing novel words in verb contexts (preceded by subject pronouns), known verbs (also preceded by subject pronouns), and known nouns (preceded by determiners). If infants group the novel words with the familiar verbs (and not with the familiar nouns) based on the fact that the novel words appeared in verb contexts, then they should look longer during the test trials presenting the novel verbs in incongruent noun contexts. Such a result would suggest that infants do pay attention to co-occurring function words: They would not group words together simply because they both appear at the end of utterances (e.g., group "eats"

[3]Infants' performance in Experiment 2 cannot be explained by a difference in the amount of exposure to the novel verbs. While the average habituation time in Experiment 1 (novel verbs) and Experiment 2 is comparable (Experiment 1: M = 127.5 s; range = 24.7–271.9 s versus Experiment 2:126.08; range = 37–263 s), the average exposure to the novel words was higher in Experiment 1 (M = 69.2) than in Experiment 2 (M = 34.19), since familiar verbs were added in the latter condition.

and "balls" after hearing "he eats" and "the balls"), but rather group words which appear in the same syntactic contexts (e.g., group "eats" and "sleeps" together after hearing "he eats" and "he sleeps").

4.1 | Method

4.1.1 | Participants

A total of 28 French-learning monolingual 14-month-olds with no known hearing problems participated in the experiments (mean age: 14 months, 0 days; age range: 13 months, 16 days–14 months, 9 days; 18 girls). An additional 12 infants were tested in the Novel Verbs + Mixed Known Words condition, but excluded from the analyses due to extreme fussiness/crying (6), failure to habituate (1), technical failure (2), or parental interference (3).

4.1.2 | Stimuli, design, and procedure

As in the previous experiments, three habituation lists were prepared. These lists were twice as long as in Exp. 1 and Exp. 2 (i.e., 58 s instead of 29.5 s) since we aimed at providing as much variety while ensuring that infants would get enough repetitions of the pseudo-words and enough support from the crucial type of semantic seed (i.e., familiar verbs). The familiar nouns were the following: *ballon* "ball," *chat* "cat," *doudou* "blankie," and *livre* "book." They appeared in noun contexts, that is, following the determiners *des* "some" and *ton* "your." Each trial presented 16 utterances with the pseudo-words and 16 utterances with familiar words (half with known verbs and half with known nouns). As in the previous experiments, the utterances were pseudo-randomized with two restrictions: A particular utterance cannot appear twice in a row, and one of the novel pseudo-word occurs at least once every three utterances. Furthermore, in order to facilitate the recognition of familiar words, the two contexts involving a particular word (e.g., *mange* "eat") were only separated by three other utterances (e.g., *je mange "I eat," des doudous "some blankies," je nuve "I nuve," il dase "he dases,"* and *il mange "he eats"*). That is, since the number of familiar words presented in the habituation lists doubled, we aimed at facilitating recognition and activation by presenting two cases of a particular familiar word in a short time window. Once again, the test trials were the same as those used in Experiment 1. The procedure is the same as in the previous conditions.

4.2 | Results

The data from the Novel Nouns condition of Experiment 1 were analyzed along with the one from Experiment 3 in a 2 × 2 analysis of variance (ANOVA) with Condition (Novel Nouns vs. Novel Verbs + Mixed Known Words) as a between-participant factor and Test Trial Type (noun vs. verb context) as a within-participant factor. The results showed no effect of Condition, nor of Test Trial Type (both $F(1, 54) < 1$). As in Experiments 1 and 2, the interaction between Condition and Test Trial Type was significant ($F(1, 54) = 9.770$, $p = .003$, $\eta^2 = 0.153$), that is, the two groups behaved differently during the test phase. A follow-up paired t test assessed the performance in Experiment 3. With a habituation phase that mixed novel verbs and familiar nouns and verbs, we obtained a significant difference between the congruent test trials presenting verb contexts ($M = 10.17$, $SE = 0.832$) and the

incongruent test trials presenting noun contexts ($M = 13.10$, $SE = 1.265$), $t(27) = -2.316$, $p = .028$, $d = -0.438$. A total of 18 infants out of 28 showed the expected pattern of listening times.

Note that infants from Experiment 3 were habituated to the novel words to the same extent as those from Experiment 2 (Experiment 2: $M = 126.09$ s, range = 37–263 s; Experiment 3: $M = 120.3$ s, range = 17.6–292.2 s), yielding an average exposure to the novel words of about 34 times (Exp. 2: 34.2 times; Exp. 3: 33.2 times). Nevertheless, the design of Experiment 3 yielded a different exposure to the known words in terms of quantity and quality. First, familiar verbs were heard on average 34.2 times in Experiment 2 (Novel Verbs + Known Verbs) and only 16.6 times in Experiment 3 (Novel Verbs + Mixed Known Words), since familiar nouns were also presented about 16.6 times. In addition, two phrases involving a particular familiar verb (e.g., *je mange* "I eat" and *il mange* "He eats") were separated on average by seven utterances (range: 2–12) in the habituation trials of Experiment 2, whereas they were separated by only three utterances in Experiment 3, which might have promoted recognition of the known verbs.

To compare the behavior of the infants from the verb groups, we ran an ANOVA with all three verb groups (Exp. 1, Exp 2, and Exp 3): This analysis revealed a significant and strong effect of Trial Type ($F(1, 81)=9.857$, $p = .002$, $\eta^2 = 0.108$), showing that overall, 14-month-olds expected novel verbs that had been presented in verb contexts to occur in other verb contexts (i.e., preceded by a subject pronoun). In addition, there was no interaction between Condition and Trial Type ($F(1, 81) = 0.38$, $p = .69$, $\eta^2 = 0.008$), suggesting that the three groups of infants did not behave differently.

4.3 | Discussion

In a series of three pre-registered experiments, we showed that 14-month-olds who are habituated to novel words preceded by common function words can build expectations about the syntactic contexts in which they are likely to be next encountered (co-occurring with a determiner or a pronoun). We first confirmed earlier findings indicating that 14-month-olds expect novel words heard in noun contexts (preceded by determiners) to later occur in other noun contexts (in Quebec French: Shi & Melançon, 2010; in German: Höhle et al., 2004). Crucially, we went on to demonstrate that infants' sensitivity to the co-occurrence of verbs with pronouns begins much earlier than previously understood. At 14 months, French-learning infants can infer that a novel word heard in the context of subject pronouns is more likely to be heard following a different subject pronoun, than following a determiner, as shown in the overall analysis pooling together infants from all three verb groups (total of 84 infants). This effect was present even when familiar verbs and familiar nouns were both presented along with the novel words during the habituation phase (Experiment 3). Hence, when infants were familiarized with pronouns followed by novel words, they were not simply expecting more pronouns to occur later on. Instead, they paid attention to the specific co-occurrences between pronouns and novel words to build expectations about the other contexts that these novel words are likely to occur in.

We started out this set of experiments under the hypothesis that 14-month-olds were in all likelihood able to track co-occurrence patterns between function words/morphemes and verbs (in languages such as French or English), since only a few months later, at the age of 18 months, they have been shown to exploit such co-occurrences to infer the probable meaning of a novel word (e.g., "he's larping," "larp" likely refers to an action; de Carvalho et al., 2019; He & Lidz, 2017). Because previous experiments had failed to reveal an ability to track verb distributional contexts (Höhle et al., 2004; Shi & Melançon, 2010) and because we think that children have to rely on known content words in order to learn which contexts correspond to which categories (e.g., objects/actions), we speculated

that adding familiar content words to the habituation lists might help infants to retrieve their knowledge about verb contexts. We did not find clear evidence that this was so, since there were no significant differences in infants' performance between the three conditions presenting novel verbs (with or without familiar words during the habituation phase). At any rate, even if adding familiar words to the habituation phase had significantly improved infants' performance in the task, this finding could not have been taken as direct evidence of the process through which they had learned distributional regularities. The improvement might simply be due to the fact that the task was made less boring, and/or more ecological (i.e., familiar words are present in typical child-directed input, and these familiar words might act as helpful contrasts/anchors for novel words).

Since our experiments did not test the meaning associated with the novel words, we can say nothing about whether infants went all the way up to evaluating their likely semantic properties or whether they remained at the stage where only distributionally based predictions (likelihood of co-occurring function words) are generated. It is unknown whether, at 14 months of age, infants can expect the novel words not only to appear in the same contexts as the familiar verbs, but also to share some semantic properties with them based on their conceptual category (e.g., refer to an action that can be performed by an agent). Note that teaching novel verb–event associations has been challenging in laboratory settings at this age. For instance, while 18-month-olds have been shown to categorize a novel verb and infer its meaning based on its syntactic context in recent studies using a habituation-switch paradigm (in French: de Carvalho et al., 2019; in English: He & Lidz, 2017), younger infants (14-month-olds) failed to do so with the same design (He & Lidz, 2017). Even older children have difficulty learning the meaning of novel verbs in "sparse" contexts (when the referent of the subject pronoun is uncertain, as in our study; see Arunachalam & Waxman, 2011; Syrett, Arunachalam, & Waxman, 2014). Hence, given young infants' limited processing and mapping skills, novel paradigms need to be developed in order to discover the full scope of infants' early representations of newly learned words during the initial stages of syntactic and lexical acquisition.

In sum, we have shown that by 14 months, infants notice the syntactic contexts in which known nouns and verbs occur. Although verbs occur in less consistent contexts than nouns in French, French-learning infants nonetheless pay attention to their co-occurrence patterns with specific function words. This knowledge is a powerful tool that can be deployed when new words are encountered, enabling infants to build expectations about their properties. Most importantly, infants around this age have already acquired rudimentary levels of syntactic and lexical knowledge that are highly connected, and greatly influence one another.

ACKNOWLEDGMENTS

This research was supported by postdoctoral fellowships to Mireille Babineau, one from the Fyssen Foundation and another from the H2020 European Research Council [Marie Skłodowska-Curie Grant No 799380). It was also supported by grants from the Fondation de France and the French ANR (ANR-13-APPR-0012 LangLearn, ANR-17-CE28-0007-01 LangAge, and ANR-17-EURE-0017 FrontCog). The authors thank Anne-Caroline Fiévet for her help in recruiting the children. We also thank all the parents and the children who participated in this study.

CONFLICT OF INTERESTS

The authors declare no conflicts of interest with regard to the funding source for this study.

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How to cite this article: Babineau M, Shi R, Christophe A. 14-month-olds exploit verbs' syntactic contexts to build expectations about novel words. *Infancy*. 2020;25:719–733. https://doi.org/10.1111/infa.12354